Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 85 (2016) 472 – 480

Energy Procedia

Sustainable Solutions for Energy and Environment, EENVIRO - YRC 2015, 18-20 November 2015, Bucharest, Romania

Factors which influence the thermal comfort inside of vehicles

Mihaela Simion[a], Lavinia Socaciu[a*], Paula Unguresan[a]

[a] *Technical University of Cluj-Napoca, Faculty of Mechanical Engineering, Departament of Mechanical Engineering, Romania*

Abstract

This research paper presents a review of factors which influence the thermal comfort inside of vehicle. These factors can be classified in two classes: measurable factors, which include: the air temperature, air velocity, radiant temperature and relative humidity and personal factors which include: activity level and clothing insulation. An optimal level of the thermal comfort inside a vehicle can only be achieved by taking into account these measurable and personal factors. Based on these factors we can calculate Predicted Mean Vote (PMV) which represents the average thermal sensation felt by a group of people placed in the vehicle and determining the Predicted Percentage of Dissatisfied (PPD) index, which is the quantitative measure of thermal comfort of a group of people at a particular environment.

Peer-review under responsibility of the organizing committee EENVIRO 2015
Keywords: Factors of thermal comfort inside the vehicle; air temperature; air velocity; radiant temperature; relative humidity in the vehicle; activity level; clothing insulation

1. Introduction

Thermal comfort is that condition of mind which expresses satisfaction with the thermal environment [1]. Thermal comfort is a subjective term defined by a plurality of sensations and is secured by all factors influencing the thermal condition experienced by the occupant, therefore is difficult to give a universal definition of this concept [2]. The thermal comfort sensation is assured by the factors that depend on the heat exchange between the human body and the ambient environment [3]. Thermal comfort is the human being’s thermal sensation of the surrounding environment, which express the level of satisfaction of thermal environment [4].

* Corresponding author. Tel.: +4-075-221-3545.
E-mail address: lavinia.socaciu@termo.utcluj.ro.

Peer-review under responsibility of the organizing committee EENVIRO 2015
doi:10.1016/j.egypro.2015.12.229

Because the people are different, in same condition, the thermal sensation perceived can be different. This means that the environmental conditions required for comfort are not the same for everyone.

There are six primary factors that must be approach when defining conditions for thermal comfort. These factors can be classified in two classes: measurable factors and personal factors. The measurable factors include: the air temperature, air velocity, radiant temperature and relative humidity. The personal factors include: activity level and clothing insulation. To realize the study of thermal comfort inside the vehicle must be taken into account all of these factors because they may vary in time and because each person has a different comportment; thus it is difficult to satisfy every person placed in a closed space, like inside the vehicle environments.

Because human beings are different, thermal comfort usually refers to a set of optimal parameters, for which the highest percentage possible of a group of people, feel comfortable about the environment [2]. The Fanger model is represented by the Predicted Mean Vote (PMV) index, which is based on the thermoregulation and the heat balance theories to help predict the thermal comfort.

The PMV index provides a score that corresponds to the ASHRAE thermal sensation scale and represents the average thermal sensation felt by a large group of people [5]. The PMV establishes thermal strain based on a steady-state heat transfer between the human body and thermal comfort ratings from panel subject. The PMV has been proposed and established for homogenous conditions only and when applied in non-homogenous conditions as the case in vehicular cabins, it did not provide accurate prediction [6]. In PMV index measurable parameters were taking into consideration, such as a band of interior temperature and humidity range that is prescribed to satisfy at least 80% of the vehicle occupants. PMV index can be determined when the personal factors (human activity level and clothing insulation) are estimated and the environmental factors (air temperature, air velocity, radiant temperature and relative humidity) are measured.

Fanger also noted that the values of PMV are not sufficient to define the feeling of discomfort, as slightly warm or too cold, don’t express how dissatisfied people are. Therefore, the idea of Predicted Percentage of Dissatisfied (PPD) was associated to the PMV calculation. The PPD calculates a prediction of the number of thermally dissatisfied people [7]. Even with the votes equal to zero (comfortable), 5% of the people are dissatisfied, and in extreme conditions 100% of the people are dissatisfied [8].

Berkeley model provide a sophisticated thermal comfort models by using a virtual thermal manikin to represent the human thermoregulatory system in addition to representing the local and overall sensations, all this can be done in non-uniform and transient conditions. Each segment of Berkeley manikin is modelled as four body layers (core, muscle, fat and skin tissues). Physiological mechanism such vasodilation, vasoconstriction, sweating and metabolic heat production are explicitly considered in model. Convection, conduction (such as to a car seat) and radiation between the body and the environment are all treated independently [9].

Most of the automotive manufacturers had focused on increasing human thermal comfort. To achieve a high thermal comfort, most manufacturers provide a system for their cars to ensure ventilation, heating and cooling air in the passenger compartment [3]. Thermal comfort inside vehicles was highly regarded as one of the most important factors when vehicular thermal environments were designed. A comfortable thermal sensation could bring the occupants not only a great felling and a good physical state but also more concentration and motivation at work or in life which brings a tremendous contribution to the work efficiency and to life quality [4].

There are several researches regarding the thermal comfort inside of vehicles in the scientific literature, but the number of studies which focus on analysing the factors is just a few. The attention of researchers is concentrate mainly on methods of evaluation the thermal comfort.

Alahmer et al., in [10] reviewed vehicular thermal models comprehensively. In their study was discussed and analysed each of the thermal indices that were typically used in assessing in-cabin condition such as PMV index and PPD. In [11] the researchers investigates the analysis and modelling of vehicular thermal comfort parameters using a set of designed experiments aided by thermography measurements. In [9], discuss about the development of the thermal comfort zones during summer and winter periods inside vehicular cabins using two thermal modelling approaches: Berkeley and Fanger computation.

Croitoru et al., in [2] reviewed the thermal comfort models and methods assessing thermal comfort in buildings and vehicular spaces. In their study presented the physiological base of thermal comfort, the main thermal comfort models and standards. Guan et al., in [12] presented a literature review regarding the advantages in thermal comfort modelling for building and vehicle ventilation, heating and cooling air applications.

In [13], Jones investigated the capabilities and limitations of thermal models. He compared several thermal sensation model outputs with measured data for a winter automobile warm-up condition and showed that the models outputs differ widely in their precision. Chakroun and Al-Fahed in [14] analysed the thermal comfort inside a car parked under the sun during summer months in Kuwait. They considered effect of using different combinations of internal covering on PMV index inside the car.

The major aim of this review was to identify and discuss about the factors involved the in study of thermal comfort inside vehicles. This review paper is a part of a research project which primary objective is to improve the thermal comfort of passenger`s vehicle.

2. Factors that influence indoor thermal comfort inside vehicles

The evaluation of thermal comfort of human body inside vehicles is related to environmental factors, factors regarding the human organism and factors regarding the clothing [2]. All contributing factors must be considered in order to achieve conditions which will be perceived as comfortable by a majority of passengers [15].

Measurable factors that influence thermal comfort are: air temperature, air velocity, radiant temperature and relative humidity. Personal factors established for thermal comfort are: activity level and clothing insulation. Measurable and personal factors are presented in figure 1(a).

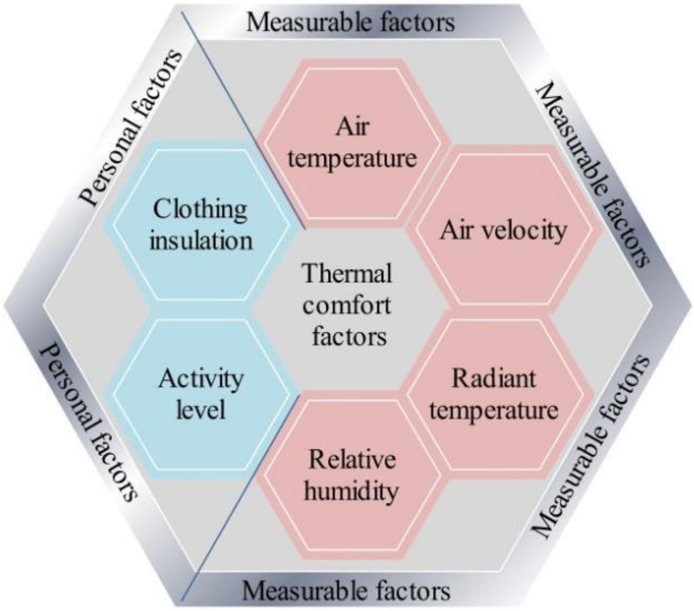

Fig. 1. Measurable and personal factor to determining the thermal comfort in vehicle

Environmental factors include: air temperature, relative humidity, air speed, radiant temperature. The factors regarding the human organism are the metabolic rate, type of activity, age, gender, weight etc. The factors concerning the clothing include thermal resistance of wear, material structure, number of layers etc. These factors have complex effects on the heat balance of passengers. Other factors like: age, health, climate, season, expectation can affect the body heat balance and the thermal comfort. Between these factors exists a strong linkage for thermal comfort zone and there are many values recommended in standards that can be used for measurements.

The sun affects thermal comfort directly when shining on people in enclosed spaces [16], such as vehicles. Indoor exposure to sunlight produces a substantial effect on the occupant`s comfort and on the air conditionings energy needed to correct it. The components contributing to thermal comfort in vehicle are presented in figure 2.

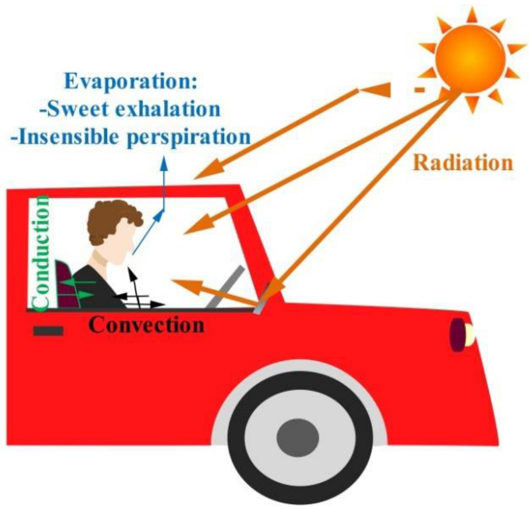

Fig. 2 Components contributing to thermal comfort in vehicle

When a vehicle is exposed to sunlight, the operator's body receives the heat partly by solar radiation transmitted through the glass and partly by long wave thermal radiation from the surrounding surfaces. The amount of solar radiation energy that will be absorbed by the body will depend on the effective projected area and on the solar absorptivity of the body surface [17]. Heat transfer can occur by convection (air currents over the body, creating a cooling effect by inducing evaporation over the skin), by conduction (contact heat transfer with other surfaces, e.g. car seat), by radiation (instantaneous infrared heat transfer with any visible object or surface at a different temperature than a person's body, e.g. the sun), or by a person's biological processes (e.g. sweating, exhalation) [18]. The interaction of convective, radiation and conduction heat exchange in the passenger's compartment is very complex. The varying radiation from the sun, the influence of inhomogeneous air temperature and air velocity from the vehicle's ventilation or air conditioning system creates a climate that may vary considerably in space and time [3]. In environmental conditions vehicles are likely to suffer considerable fluctuations: rapid changes in air temperature, solar radiation and air movement [19]. This presents problems in the evaluation and prediction of the thermal environment in vehicles.

The number of investigations on the effect of solar radiation on thermal comfort in vehicles using human subjects is particularly reduced when compared with the overall number of investigations on thermal comfort conducted in buildings. The constantly changing conditions of both internal and external environments of vehicles make it particularly difficult to study. As consumers constantly demand more of their vehicles, the need for greater understanding of thermal comfort in these complex environments must match their desire for a thermally more comfortable journey [20].

Thermal environment in passenger cars is different from those in buildings and is often highly non-uniform and asymmetric, from the following reasons: interior volume is small, compared with the number of persons; changing of microclimate parameters could be rapid (the vehicle is changing the orientation to the sun, etc.); the shape of the cabin vehicle interior is complex; glazing area is large in comparison to cabin surface; passengers seat close to surfaces with temperatures which could be significantly higher or lower than interior air temperatures; passengers are not able to change position within the cabin, and changes of body posture are limited; the air-conditioning is usually not activated when there is no occupants in the vehicle or when the engine is not running, resulting in occurrence of extreme microclimate conditions [21].

Thermal comfort of the occupants in a vehicle cabin is a growing concern due to occupant's health and safety. In addition to that, with more stringent requirements for efficient utilization of energy resources, the transport industry must rely on improving energy efficiency of vehicles [22, 23]. With this respect, engineers have to consider energy consumption during heating or cooling of an automobile cabin due to legal restrictions and efficient use of energy resources. In the early stage of vehicle design the need to reduce heat loads that enter passenger compartments has become an important issue and the radiation has an important role on the thermal comfort in the car compartment [24, 25]. Thus, engineers have to design more effective ventilation, heating and cooling air systems of automobiles under different environmental conditions [26].

Considering the multitude of parameters that can directly influence thermal comfort, it is necessary to achieve and maintain thermal equilibrium between human body - indoor space - environments, because the human body continuously varies the ratio between the heat produced and transferred [2].

3. Measurable factors that influence indoors thermal comfort in vehicle

3.1. Air temperature

In many researches the air temperature is defined as the average temperature of air surrounding the body, with respect of location and time. The air temperature inside of vehicles depends on: season time and the position on globe of vehicle.

The air temperature inside the vehicles is inhomogeneous due to the installed air conditioning system [4]. According to the requirements for thermal comfort in summer conditions, interior air temperature should be in the range of 23 to 28°C [27].

The parameters for air temperature include the mean interior temperature and the criteria for horizontal and vertical temperature distribution in order to reduce areas of local thermal discomfort to minimum. Different requirements were also defined for surface temperatures. These requirements represent a compromise between subjective desires and what is possible in practice [15].

The spatial average takes into account the ankle, waist and heat levels [1], which vary for seated or standing occupants [4]. Inside vehicles, the air temperature at the bottom of cabin (ankle level) is expected to be higher than at top of cabin (head level). In this case, for the vertical air temperature [1] prescribe 3ºC difference between head and ankle level [28]. These variations can lead to thermal discomfort which can affect the driver concentration on driving and also the passenger wellbeing.

The air temperature depends on the cabin space of vehicles. At the same driving conditions, a larger vehicle may have an absolute different air temperature than a small economy-class vehicle [4]. Other differences of air temperature are given by the "class of vehicle and upholstery fabric" - a wider vehicle cabin with leather upholstery may have a different air temperature in respect with human body and warm-up (or cooling) conditions, compared with a small economic-class cabin vehicle.

3.2. Relative humidity

In [1] the relative humidity (RH) was defined as the ratio of the amount of water vapour in the air to the amount of water vapour that the air could hold at the specific temperature and pressure [28]. The recommended values for inside temperature and air humidity correlated with the outside temperature are given in Table 1.

Table 1. Values for inside temperature and air humidity in correlation with the outside temperature [28]

Season	Outside temperature (°C)	Inside temperature (°C)	Minimum relative humidity (%)	Maximum relative humidity (%)
Winter	≤±20	22	35	70
Summer	+20	22	not available	70
	+25	23	not available	65
	+30	25	not available	60
	+32	26	not available	55

Relative humidity between 30% ~ 70% doesn't influence thermal comfort. When RH is over 70%, it will prevent the sweat evaporation and then cause sultry weather sensation and let occupants fell discomfort. When RH is lower than 30%, it will cause dry sensation and has a bad effect on mucous membranes [4].

Fountain et al., in [29] has investigating the influence of high humidity levels on human comfort. In this study articulated the qualitative relative humidity effects without distinguishing it from other variables mainly the dry bulb temperature.

Alahmer et al., in [7] discussed about the effect of manipulating the relative humidity on the in-cabin environment from the thermal comfort and human occupants thermal sensation perspectives using thermo-dynamics and psychometric analyses and using a Berkeley and Fanger simulation model, in [30].

3.3. Mean radiant temperature

The mean radiant temperature of an environment is defined as the uniform temperature of an imaginary black enclosure which would result in the same heat loss by radiation from the person as the actual enclosure [4].

There are several methods of measuring and modelling the mean radiant temperature. The most complex and accurate measurement technique is the performance of integral radiation measurements and the calculation of angular factors, presented in [31-33].

The mean radiant temperature can be calculated if is known the surfaces, the temperature which separates the passenger's area, respectively the temperature and the position for every construction element around passenger inside the vehicle.

3.4. Air velocity

Air velocity is defined in [1] as the average speed of the air to which the body is exposed, with respect the location and time. Human body is very sensitive with air movement especially in some parts like the neck, the head and the feet and it also depends on person's sensitivity. If the flow rate is too high or irregular, then local thermal discomfort appears. Thus, it's very important to easily control the air velocity and the flow direction [34].

The working principle of the vehicle air-conditioning and the ventilation system is based on driving the conditioned air through adjustable air vents inside the vehicle cabin. This airflow causes changes in local and overall microclimate conditions, consequently also changing the heat loss from the operator's body. This airflow is characterized by spatially distributed local air velocities and air temperatures [35]. Some studies focused on understanding how air flows through different types of diffusers [27, 36-39] and how the people comfort can be improved by the passive control of the air jets.

Air velocity inside the vehicle is in correlation with many factors. The air flow from the air conditioning increases the air velocity inside the vehicle, and the values of air flow velocity vary between 0.1 ÷ 0.4 m/s [28]. Main requirements regarding preferable combination of local air velocity and temperature system should meet are: to attain and keep local skin temperature within comfort range; to penetrate natural airflow around the body; to avoid draught or eye irritation; to supply the breathing zone with fresh clean air [21].

4. Personal factors that influence indoors thermal comfort in vehicle

4.1. Human activity level

Humans require energy to perform work and produce heat to maintain the internal body temperature around 36.5°C. The higher activities level is more intense, the more heat is produced. If is produced too much heat then the body will sweat which will cause discomfort. If is produced too little heat then the blood will be withdrawn from the hands and feet, the skin temperature will fall and the person will feel cold and uncomfortable [40, 41]. Activity level has a strong influence on human thermal sensation, comfort and indoor temperature preferences [42]. In table 2 are presents an estimation of metabolic rate for basic activity.

Table 2. Estimate of metabolic rate for basic activity [7]

Basic activity	Estimate of metabolic rate
Lying down	0.8 met – 47 W/m2
Sitting quietly	1.0 met – 58 W/m2
Seated office work	1.2 met – 70 W/m2
Light work	1.6 met – 93 W/m2
Medium work	2.0 met – 117 W/m2
Heavy work	3.0 met – 175 W/m2

4.2. Clothing insulation

Clothing is needed to protect the human body against hostile climate condition and assists in the thermo regulatory of the body by maintain the thermal balance between skin and the atmosphere [43]. The thermal comfort is related to fabrics ability to maintain skin temperature and allow transfer of perspiration produced from the body [43, 44]. The insulating properties of clothing it is measured in clo [45]. In table 3 are presents an estimation of some types of clothing insulation.

Table 3. Clothing Levels and Insulation [7]

Description	Thermal insulation range (Clo)
Winter outdoor clothing	2-3
Normal indoor clothing	1.2-1.5
Summer indoor clothing	0.8-1.2
Indoor „Lightweight” clothing	0.3-0.5

Clothing insulation could reduce the heat loss from body and influence the heat balance, which means that it could either keep body warm or lead to overheating. Human body has different skin temperature of each different part. By adding or removing the layers of clothing, occupants could try to adapt the vehicular environment as the most direct way [28].

In generally, the main factors leading to the reduction of clothing insulation are: air speed (increased air speed decreases clothing insulation), body movements (pumping action breaks up air layer), water vapour transfer (clothing offers a resistance to passage of water vapour and decreases heat loss by evaporation from skin).

5. Conclusions

Factors that influence thermal comfort inside the vehicles have been analysed so that their influence on vehicle can be determined with high accuracy. The car environment is defined with help of the six thermal comfort factors.

The measurable factors include: air temperature, relative humidity, mean radiant temperature and air velocity. Measuring each parameter requires a lot of instrumentation and it is difficult to measure all the parameters in the exact same location and then later calculate the combined influence. Usually, the personal factors, which include the human activity level and clothing insulation, are estimated. These factors are independent, but together they contribute to establish the thermal comfort. If one factor suffer changes, then others factors need to be adjusted to maintain the thermal comfort.

The thermal comfort inside the vehicle differs significantly from buildings. The air temperature is correlated to a greater extent with relative air humidity, and they influence the thermal comfort of the passenger.

The air velocity influences the thermal comfort inside the car because the human body is very sensitive, in some limits, with the air movements.

Another parameter with a major importance on thermal comfort inside vehicles, but with less importance in the case of buildings is the solar radiation.

Acknowledgements

This work was supported by Grant of the Romanian National Authority for Scientific Research, CNCS, UEFISCDI, Projects number: PN-II-PT-PCCA-2013-4-0569 Innovative strategies of HVAC systems for high indoor environmental quality in vehicle and PN-II-PT-PCCA-2011-3.2-1212 Advanced strategies for high performance indoor Environmental Quality in Operating Rooms.

References

[1] ASHRAE, Thermal environmental conditions for human occupancy. In: ANSI/ ASHRAE standard 55-2013, American Society of heating, refrigerating and air-conditioning engineers, (2013) 1-26.
[2] Croitoru C., Nastase I., Bode F., Meslem A., Dogeanu A., Thermal comfort models for indoor spaces and vehicles—Current capabilities and future perspectives, Renewable and Sustainable Energy Reviews, 44 (2015) 304-318.
[3] Ivanescu M., Neacsu C., Tabacu S., The human thermal comfort evaluation inside the passenger compartment, in: World Automotive Congress, Budapest, Hungary, 2010.
[4] ZhOU Q., Thermal Comfort In Vehicles, in, Faculty Of Engineering And Sustainable Development, 2013.
[5] Simons B., LKoranteng C., Adinyira E., Ayarkwa J., An Assessment of Thermal Comfort in Multi Storey Office Buildings in Ghana, Journal of Building Construction and Planning Research, 2 (2014) 30-38.
[6] Alahmer A., Effect of reative humidity and temperature control on in-cabin thermal comfort state, in, Clemson University, 2011.
[7] Alahmer A., Effect of relative humidity and temperature control on in-cabin thermal comfort state, in, Clemson University, 2011.
[8] Hott M. V. M., Pereira L. V. M., Maia C. B., Subjective evaluation of thermal comfort in vehicle, in: ACBM (Ed.) 20th International Congress of Mechanical Engineering, Gramado, 2009.
[9] Alahmer A., Omar M.A., Vehicular Cabins thermal Comfort Zones: Fanger and Berley modeling, Vehicle Engineering, 1 (2013) 19-32.
[10] Alahmer A., Mayyas A., Mayyas A.A., Omar M.A., Shan D., Vehicular thermal comfort models; a comprehensive review, Applied Thermal Engineering 31 (2011) 995-1002.
[11] Alahmer A., Abdelhamid M., Omar M.A., Design for thermal sensation and comfort states in veicles cabin, Applied Thermal Engineering, 36 (2012) 126-140.
[12] Guan Y., Hosni M.H., Jones B.W., Gielda T.P., Literature review of the advanced in thermal comfort modelling, ASHRAE Trans, 109 (2003) 908-916.
[13] Jones B.W., Capabilities and limitations of thermal models for use in thermal comfort models, Energy and Buildings, 34 (2002) 653-659.
[14] Chakroun C., Al-Fazed S., Thermal comfort analysis inside a car, Int. J. Energy Res., 21 (1997) 327-340.
[15] Haller G., Thermal Comfort in rail vehicles, in, 2006.
[16] Hodder S. G., Parson K., The effects of solar radiation and black body re-radiation on thermal comfort, Ergonomics, 51 (2008) 476-491.
[17] Ružić D., Časnji F., Thermal Interaction Between a Human Body and a Vehicle Cabin in, Intech.
[18] Regnier C., Guide to Setting Thermal Comfort Criteria and Minimizing Energy Use in Delivering Thermal Comfort, in: E.O.L.B.N. Laboratory (Ed.), 2012.
[19] Temming J., Comfort requirements for heating, ventilation and air conditioning in motor vehicles, Research and Development Division, Volkswagenwerk AG, (1980).
[20] Hodder S. G., Parsons K., The effects of solar radiation on thermal comfort, Int. J. Biometeorol, 51 (2007) 233-250.
[21] Ružić D., Improvement of thermal comfort in a passenger car by localized air distribution, Acta Technica Corviniensis - Buletin of engineering, 4 (2011) 63-67.
[22] Jovic J.J., Djoric V. D., Application of Transport Demand Modelling in Pollution Estimation of a Street Network, Thermal science, 13 (2009) 229-243.
[23] Manojlovic A. V., Papic V. D., Filipovic S. M., Fleet Renewal: An Approach to Achieve Sustainable Road Transport, Thermal science, 15 (2011) 1223-1236.
[24] Kilic M., Sevilgen G., Evaluation of Heat Transfer Characteristics in an Automobile Cabin with a Virtual Manikin during Heating Period, Numerical Heat Transfer, Part A: Applications, 56 (2009) 515-539.
[25] Huang L., Han T., Validation of 3-D Passenger Compartment Hot Soak and Cool-Down Analysis for Virtual Thermal Comfort Engineering, SAE International Technical Paper, (2002).
[26] Sevilgen G., Kilic M., Investigation of transient cooling of an automobile cabin with a virtual manikin under solar radiation, Thermal science, 17 (2013) 397-406.
[27] Meslem A., Bode F., Croitoru C., Nastase I., Comparison of turbulence models in simulating jet flow a cross-shaped orifice, Eur. J. Mech. B-Fluids, 44 (2014) 100-120.
[28] Musat R., Helerea E., Parameters and Models of the Vehicle Thermal Comfort Acta Universitatis Sapientiae, Electrical and Mechanical Engineering, 1 (2009) 215-226.
[29] Fountain M., Arens E., Xu T., Bauman F., Oguru M., An investigation of thermal comfort at igh humidities, ASHRAE Trans, 105 (1999) 94-103.
[30] Alahmer A., Omar M.A., Mayyas A., Qattawi A., Analysis of vehicular cabins, thermal sensation and comfort state, under relative humidity and temperature control, using Berkeley and Fanger models, Building and Environment, 48 (2012) 146-163.

[31] Hoppe P., A new procedure to determin the mean radiant temperatures outdoor, Wetter und Leben, 44 (1992) 147-151.
[32] Spagnolo J.C., de Dear R.J., A field study of thermal comfort in outdoor and semi-outdoor environments in subtropical Sydney Australia, Building and Environment, 38 (2003) 721-738.
[33] Ali-Toudert F., Mayer H., Outdoor thermal comfort in the old desert city of Beni-Isquen, Algeria, Climate research, 28 (2005) 243-256.
[34] Riachi Y., Clodic D., A numerical model for simulating thermal comfort prediction in public transportation buses International Journal of Environmental Protection and Policy, 2 (2014) 1-8.
[35] Ružić D., Časnji F., Thermal Interaction Between a Human Body and a Vehicle Cabin, in: S.N. Kazi (Ed.) Heat Transfer Phenomena and Applications, INTECH, 2012.
[36] Bode F., Meslem A., Croitoru C., Numerical simulation of a very low Reynols cross-shaped jet, Mechanika, (2013) 512-517.
[37] Bode F., Nastase I., Meslem A., Croitoru C., RANS and LES Models of a Lobed Jet Flow Integrated in a Personalized Ventilation System, in: The 11th REHVA World Congress and the 8th International Conference on Indoor, Air Quality, Ventilation and Energy Conservation in Buildings, Prague, 2013.
[38] Meslem A., Nastase I., Bode F., Beghein C., Optimization of a lobed perforated panel diffuser - a numerical study of orifice arrangement, Int. J. Vent., 11 (2012) 255-270.
[39] Bode F., Nastase I., Meslem A., Croitoru C., RANS and LES models comparison for a cross shaped jet flow with application in personalized ventilation, in: Joint conference 33rd AIVC conference and 2nd TightVent Conf., Copenhagen, Denmark, 2012, pp. 113-117.
[40] Parson K., The estimation of metabolic heat for use in the assessment of thermal comfort, in.
[41] Appah-Dankyi J., Koranteng C., An assessment of thermal comfort in a warm and humid school building at Accra, Ghana Advances in Applied Science Research, 3 (2012) 535-547.
[42] Kumar A., Singh I. P., Sud S. K., An approach towards development of pmv based thermal comfort smart sensor, International Journal On Smart Sensing And Intelligent Systems, 3 (2010) 621-642.
[43] Li Y., The science of clothing comfort,, The textile progress, 31 (2001) 1-135.
[44] Alam S., Ghosh A., Selection of cotton fabrics for optimal comfort properties using multi-criteria decision making, Journal of textile and apparel technology and management, 8 (2013) 1-8.
[45] Abhishek R., Balachander R., Thermal comfort in a closed space based on closed loop temperature control, in: Department Of Electrical Engineering National Institute Of Technology Rourkela, 2009-2010.